Endovascular repair of thoracic aortic traumatic transections is a safe method in patients with complicated injuries

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Purpose: **Historically thoracic aortic rupture secondary to trauma was treated with cardiopulmonary bypass and open surgery. With the advent of endovascular grafting, physicians have the ability to reconstruct the thoracic aortic transection using a less invasive technique. In this study, we examine our experience with stent graft repair of thoracic transections secondary to trauma.**

Methods: **The medical records of patients treated at a level I trauma center from 2005 to 2008 were reviewed. Those patients who had an aortic transection treated with an endograft were identified and evaluated for in-hospital mortality and morbidity and concurrent injuries. Demographics, procedural details, and outcomes were analyzed.**

Results: **Over a 3-year period, 18 thoracic aortic transections secondary to trauma were identified in patients with a mean age of 43 (range, 16-80). Primary technical success was 100%. None of the patients required explant or open repair during this time period. In-hospital mortality was 2 of 18 (11%); all patients had multiple trauma including long bone fractures. The subclavian artery origin was covered by the stent graft in 9 of the 18 patients. The mean estimated blood loss per procedure was 222 cc. No patient in this series had postoperative paraplegia. Follow-up ranged from 1 to 50 months with an average of 13 months. There have been no late explantation or device failures identified.**

Conclusion: **Endovascular repair of traumatic thoracic aortic transections can be performed safely with a relatively low mortality and morbidity and should be the procedure of choice for patients presenting with traumatic thoracic aortic ruptures. (J Vasc Surg 2010;52:891-6.)**

Thoracic aortic transection is a morbid condition that historically was difficult to manage. The treatment involved open surgery and aortic cross clamping with its associated significant morbidity and mortality. These injuries are related to blunt trauma and most are caused by deceleration related to motor vehicle accidents.[1] Rupture of the thoracic aorta is the second most common cause of death from motor vehicle accidents (after head injury) with an overall mortality of over 90%.[2]

There is less sudden death at the scene of motor vehicle accidents because of improved safety features with newer automobiles. Therefore, more patients are arriving at the emergency department with significant deceleration injuries. This frequently involves shearing or bending stresses from movement of the relatively mobile aortic arch with respect to the descending thoracic aorta.[3] Of the patients arriving to the hospital alive, 60% to 70% will survive if given the appropriate and timely treatment.[4] In acute aortic injury, multiple traumatic injuries frequently coexist and further increase the mortality rate.[5] Thoracic stent grafting allows for expeditious exclusion of the injury with less stress on the multi-injured patient.

In the case of nonpenetrating thoracic aortic injury, the location of the lesion is at the isthmus approximately 90% of the time.[6] The landing zone is the key component to successful endovascular repair. To achieve a reliable seal, landing zones of at least 1.5 cm are recommended.[7] This is problematic, as approximately one-half of the patients with aortic rupture are within 1 to 2 cm of the left subclavian artery, implying that the origin of this vessel will have to be crossed in a significant number of cases. However, the clinical experience suggests that this does not provide an acute risk of limb ischemia, and late "steal" phenomenon can be electively treated with carotid-subclavian bypass when the patient has stabilized.[7]

One important question is regarding timing of the intervention. These are patients with multiple injuries, some of which may take precedence over the stable periaortic hematoma. Some authors suggest that delayed repair of hemodynamically stable thoracic aortic injuries reduces morbidity and mortality. Delayed repair allows the trauma team to surgically optimize the multi-injured patient before a major surgical insult.[8,9]

METHODS

We retrospectively reviewed the medical records of all patients treated at our level I trauma center diagnosed with

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a traumatic aortic transection who were treated from 2005 to 2008 using stent graft technology. These patients were evaluated for in-hospital mortality and morbidity and concurrent injuries. Demographics, procedural details, and outcomes were analyzed.

The demographics included injury severity score, the cause of transection, and the endograft used. The procedural details included the number of endograft components used, graft sizes, whether the subclavian artery was covered, whether heparin was administered, and any adjunctive procedures that were required. Patient outcomes also included any operative revision.

RESULTS

Over the study period, 18 thoracic aortic transections secondary to trauma were identified in patients with a mean age of 44 (range, 16-80). Primary technical success was 100%. None of the patients required explant or open repair during this time period. In-hospital mortality included 2 of 18 (11%); all patients had multiple blunt trauma including long bone fractures. The subclavian artery origin was covered by the stent graft in 9 of 18 patients. The mean estimated blood loss per procedure was 222 cc. No patient in this series suffered postoperative paraplegia. Follow-up ranged from 1 to 50 months with an average of 13 months. To date, there have been no explantation or device failures identified (Table I).

After the patients were evaluated and diagnosed, all but 1 patient were taken directly from the emergency department to the endovascular suite in the operating room. With the patient under general anesthesia, a 5F sheath was placed with a contralateral groin cutdown for placement of either a 22F or 24F sheath for device delivery. Patients were systemically anticoagulated with heparin at the discretion of the attending surgeon. Left subclavian revascularization was also performed based on patient stability and status of the vertebral arteries. All devices were oversized 10% to 20%, and after deployment, the endograft was molded as necessary using a compliant balloon. Completion angiograms were performed and patients were followed postoperatively with serial computed tomography (CT) scans at 6 weeks and then 6 months thereafter. One patient was taken to the operating room 4 days later due to initial instability.

Graft deployment was successful in all cases. Technical success was defined as successful endograft deployment excluding the area of injury, as demonstrated on completion angiogram. All cases were performed from the femoral arteries without need for brachial access. All the cases except one were performed without a conduit for access. In 1 patient, an attempt was made at passing the TAG device (W. L. Gore & Associates, Inc, Flagstaff, Ariz) which was successful with the first component but the second component became lodged in the right external iliac artery, therefore, requiring an ilio-femoral bypass. The cause of the transection was an automobile accident in 14 patients, motorcycle accident in 3, and an off-road all-terrain vehicle accident in 1.

Table I. Patient characteristics

Thoracic transections	*Total*	*% of total*
2005-2008		
Total	18	
Demographics		
Male	16	88.88%
Female	2	11.11%
Diabetic	2	11.11%
Smoker	2	11.11%
Coronary artery disease	2	11.11%
Hypertension	5	27.77%
COPD	1	5.55%
Hypercholesterolemia	1	5.55%
Mean age	43	
Age range	16-80	
EBL		
Mean	222 cc	
Range	100-600 cc	
Cause of transection		
Car accident	14	77.77%
Motorcycle accident	2	11.11%
ATV accident	1	5.55%
Dirt bike accident	1	5.55%
Adjunctive procedures		
Iliofemoral bypass	1	5.55%
Carotid-subclavian bypass	1	5.55%
Subclavian-carotid transposition	1	5.55%
Permacath placement	1	5.55%
None	15	83.33%
Op mortality	2	11.11%
Cardiac	1	5.55%
MSOF	1	5.55%
Non-fatal complications	8	44.44%
Stroke	1	5.55%
Bleeding	1	5.55%
Wound infection	1	5.55%
Pulmonary	2	11.11%
MSOF	1	5.55%
Ileus	1	5.55%
Stent graft failure->rupture	1	5.55%
Endoleak	1	5.55%
Type 1A endoleak	1	
Revisions		
Redo TEVAR (s/p rupture)	1	5.55%
Follow-up (mo)		
Mean	13	
Range	1-50	

ATV, All terrain vehicle; *COPD,* chronic obstructive pulmonary disease; *EBL,* estimated blood loss; *MSOF,* multisystem organ failure; *Op,* operative; *s/p,* status post; *TEVAR,* thoracic endovascular aneurysm repair.

Adjunctive procedures involved a left carotid-subclavian bypass and a left carotid-subclavian transposition for coverage of the left subclavian artery by the device; in both of these patients, the left vertebral artery was dominant. A common femoral endarterectomy was performed on 1 patient for occlusive disease.

There were two operative mortalities. One patient died of cardiac arrest. This patient had severe blunt chest trauma and cardiac contusion. This patient had the highest injury severity score (59), this is also the patient who was delayed going to the operating room. The other patient died of

Table II. Operative details

Age/ Gender	*Cause of transection*	*Injury severity score*	*Endograft type*	*Graft size(s) mm*	*No. pieces used*	*Was subclavian artery covered?*	*Adjunctive procedure*
42/F	Car accident	36	Zenith	30 main body	2	Yes	RT carotid-subclavian bypass
25/M	Car accident	29	TAG	28 × 10	1	No	
18/M	Car accident	38	TAG	26 × 10	1	Yes	LT subclavian-CCA transposition
23/M	Car accident	41	TAG	26 × 10	1	No	
42/M	Car accident	27	TAG	26 × 15	2	No	
51/M	Car accident	27	TAG	31 × 15	1	No	
29/M	Motorcycle accident	38	TAG	26 × 10	1	No	
70/M	Car accident	57	TAG	31 × 15	1	No	
53/M	Car accident	38	TAG	34 × 15	1	Yes	
35/M	Car accident	24	TAG	26 × 10	1	Yes	
73/M	ATV accident	43	TAG	37 × 20	1	No	
80/F	Car accident	50	TAG	38 × 15	1	Yes	
16/M	Dirt bike accident	43	AneuRx cuffs (×2)	24 × 3.75	2	Yes	
42/M	Motorcycle accident	33	TAG	28 × 10	1	Yes	
28/M	Car accident	41	TAG	26 × 10	2	Yes	
49/M	Car accident	59	TAG	31 × 10	1	No	RT CFA endarterectomy
55/M	Car accident	48	TAG	40 × 20, 45 × 20	2	Yes	
58/M	Car accident	50	TAG	37 × 15	2	No	RT iliofemoral bypass

ATV, All terrain vehicle; *CCA,* common carotid artery; *CFA,* common femoral artery; *EBL,* estimated blood loss; *EIA,* external iliac artery; *EVAR,* endovascular aortic repair; *F/U,* follow-up; *LT,* left; *MSOF,* multisystem organ failure; *OP,* operation; *Prox Ext,* proximal extension; *PT,* patient; *RT,* right; *TAG,* thoracic aortic graft (W.L. Gore & Associates, Inc, Flagstaff, Ariz).

multisystem organ failure. This patient also had very significant associated injuries. The nonfatal complications included 1 patient with a right hemispheric stroke, 1 with a wound infection, and 2 with pulmonary complications. There was also 1 patient treated with two AneuRx cuffs (Medtronic, Inc, Minneapolis, Minn) who presented at 1 month postoperatively with a ruptured aorta and this was treated successfully with a TAG device (Table II).

The mean Injury Severity Score score was 40.1 (range, 24-59). The majority of patients (89%) were treated with a TAG device. Stent graft diameters ranged from 24 mm to 40 mm. The majority of patients were treated with a single component endograft, the remainder was treated with two components. Four of the patients were systemically anticoagulated with heparin maintaining an activated clotting time over 250 seconds during the procedure with no associated bleeding complication. There was also no apparent difference in outcome in the series between patients who received one or two endograft components for treatment. There does not seem to be any difference in outcome for the patients with subclavian artery coverage. Subclavian artery coverage is generally well-tolerated in the absence of a contraindication, such as dominant left vertebral artery or coronary artery bypass with the left internal mammary, although complications have been described.[10]

One of the worst complications with thoracic aortic reconstruction is paraplegia. Paraplegia is a much less frequent occurrence with endovascular thoracic grafting.[11]

There were no episodes of paraplegia in this series even though the subclavian artery was covered without revascularization in the majority of patients. One element that may play a role in this is that the trauma is focal, therefore, there is not extensive coverage of the thoracic aorta and coverage of intercostal arteries.

DISCUSSION

Although blunt aortic injury accounts for <1% of adult level I trauma center admissions, it represents the second most common cause of death due to blunt injury, after head trauma.[12] Surgeons who deal with vascular trauma need to be equipped to deal with this problem. Endovascular repair is a less invasive means to repair this difficult area with less morbidity and mortality.

In this series, all but 1 patient were taken directly to the operating room with good outcomes rather than repair in a delayed fashion. This may be related to how efficiently the area of injury can be excluded now with newer technology and more experience of vascular specialists. Also, with the hybrid operating rooms, other life-threatening injuries can be addressed at the same time.

Table II. Continued

Why adjunctive procedure was done	*Heparin given during case?*	*EBL*	*Complications*	*Further OP*	*F/U*	*Month F/U*
Dominant left vertebral	No	300			PT alive	50
	No	500			PT alive	9
Dominant left vertebral	Yes	200			PT alive	14
	No	100			PT alive	15
	No	100			PT alive	41
	Yes	200			PT alive	1
	No	200			PT alive	30
	No	200	Bleeding, MSOF		PT died	1
	No	200			PT alive	30
	No	150			PT alive	1
	No	100	MSOF		PT alive	4
	No	100	Pulmonary, RT hemispheric stroke		PT alive	1
	No	600	Ileus, stent graft failure/rupture	EVAR w/TAG @ 1 mo for rupture/PT OK at 9 mo	PT alive	9
	Yes	100			PT alive	20
	No	150			PT alive	2
Asymptomatic stenosis	Yes	200	Cardiac		PT died	1
	No	100	Pulmonary		PT died	6
TAG device lodged in RT EIA	Yes	500	Wound infection		PT alive	6

Fig 1. Angiogram demonstrating the transection and the thoracic endograft before deployment.

Fig 2. Image of thoracic endograft after deployment.

This procedure has a relatively low morbidity and mortality for a difficult problem. Subclavian artery coverage is usually necessary due to the location of the injury, but revascularization is not always required. Treatment, therefore, must be individualized. The aortic diameter being small in the younger patients is a limitation and this can be overcome by using aortic cuffs, however, a main body is preferred because it is better supported and there is less chance for problems with the overlapping of cuffs. This is what may have contributed to the 1 patient with delayed rupture. Newer main body devices with smaller diameters will solve this problem in the future. The 1 patient with a stroke was an 80-year-old female with aortic arch disease

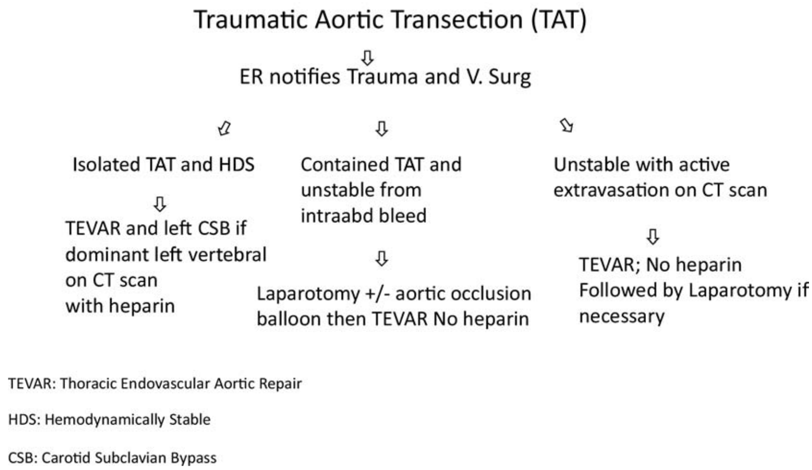

Fig 3. Protocol for the management of traumatic thoracic aortic transection. *CSB,* Carotid subclavian bypass; *CT,* computed tomography; *ER,* emergency department; *HDS,* hemodynamically stable; *intra-abd,* intra-abdominal; *TAT,* traumatic aortic transection; *TEVAR,* thoracic endovascular aortic repair; *V. Surg,* vascular surgery.

who had a right hemispheric stroke that was most likely embolic.

From a technical standpoint, the key component to successful exclusion is to get the floppy end of the stiff wire to bend off the aortic valve to allow the stiff wire to take the greater curvature of the aortic arch. This is especially important in the younger trauma patients who have a more acute angle to their aortic arch. This same principle applies to treating aneurysmal disease (Figs 1 and 2).

This injury can be treated efficiently and effectively from the femoral arteries. Brachial access and the use of a conduit are usually not necessary, although one needs to be prepared to do so. The grafts can be sized off the preoperative CT scans or with a marker catheter during angiography if the patient was too unstable to go to the CT scanner. The procedure can be performed during other life-saving procedures without the use of anticoagulation. Heparin was not used if the patient was unstable or had associated solid organ or brain injury. It is important in this case to routinely flush the sheaths to avoid clot formation. The procedure can usually be performed with one endograft component. Subclavian artery revascularization is not always necessary but it should be performed if the patient is stable and has a dominant left vertebral artery. Early postoperative imaging before the patient is discharged may be prudent to assure proper exclusion of the injured area of aorta, especially if the repair is done using overlapping cuffs which is not as structurally supported as a main endograft body.

The development of a standardized approach to treat this problem will improve outcomes as it has for treating ruptured aneurysms. We are in the process of developing a protocol to manage this clinical entity (Fig 3). Although long-term follow-up is lacking, based on the immediate outcomes and technical success of the procedure, endovascular repair should remain as the primary treatment modality.

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REFERENCES

1. Feliciano DV, Mattox KL: Thoracic and abdominal vascular trauma. In: Veith FJ, Hobson RW, Williams RA, Wilson SE, editors. Vascular Surgery: Principles and Practice. New York, McGraw-Hill; 1994. pp. 947-66.
2. Richens D, Kotidis K, Neale M, Oakley C, Fails A. Rupture of the aorta following road traffic accidents in the United Kingdom 1992-1999. The results of the co-operative crash injury study. Eur J Cardiothorac Surg 2003;23:143-8.
3. Beel T, Harwood AL. Traumatic rupture of the thoracic aorta. Ann Emerg Med 1980;9:483-6.
4. Fabian TC, Richardson JD, Croce MA, Smith JS Jr, Rodman G Jr, Kearney PA, et al. Prospective study of blunt aortic injury: Multicentre Trial of the American Association for the Surgery of Trauma. J Trauma 1997;42:374-80; discussion 380-3.
5. Mattox KL, Feliciano DV, Burch J, Beall AC Jr, Jordan GL Jr, De Bakey ME. Five thousand seven hundred sixty cardiovascular injuries in 4459 patients. Epidemiologic evaluation 1958 to 1987. Ann Surg 1989;209: 698-705; discussion 706-7.

6. Prêtre R, Chilcott M. Blunt trauma to the heart and great vessels. N Engl J Med 1997;336:626-32.
7. Karmy-Jones RC, Salerno C. Thoracic Vascular Trauma. In: Zelenock GB, Huber TS, Messina LM, Lumsden AB, Moneta GL, editors. Mastery of Vascular and Endovascular Surgery. Lippincott Williams & Wilkins; 2006. pp. 629-35.
8. Camp PC, Shackford SR. Outcome after blunt traumatic thoracic aortic laceration: identification of a high-risk cohort. Western Trauma Association Multicenter Study Group. J Trauma 1997;43:413-22.
9. Maggisano R, Nathens A, Alexandrova NA, Cina C, Boulanger B, McKenzie R, et al. Traumatic rupture of the thoracic aorta: should one always operate immediately? Ann Vasc Surg 1995;9:44-52.
10. Orend KH, Pamler R, Kapfer X, Liewald F, Görich J, Sunder-Plassmann L. Endovascular repair of traumatic descending aortic transection. J Endovasc Ther 2002;9:573-8.
11. Carroccio A, Marin ML, Ellozy S, Hollier LH. Pathophysiology of paraplegia following endovascular thoracic aortic aneurysm repair. J Card Surg 2003;18:359-66.
12. Clancy TV, Gary Maxwell J, Covington DL, Brinker CC, Blackman D. A statewide analysis of level I and II trauma centers for patients with major injuries. J Trauma 2001;51:346-51.

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